Paper XIV The Microbarographic Oscillations Produced by the Explosions of Hydrogen-Bombs (The Radioactive Dust from the Nuclear Detonation)

PAPER XIV

The Microbarographic Oscillations Produced by the Explosions of Hydrogen-Bombs

Ryōzaburo YAMAMOTO

(Meteorological Research Institute, Kyoto University)

I. INTRODUCTION

Since Jan. 1952, the three-points simultaneous microbarographic observations with the instruments constructed by T. Shida[1] (magnification power ca. 40) have been continued at Shionomisaki, Wakayama Prefecture, the southern edge of central Japan, studying the mechanism of microbarographic waves of meteorological origins under the direction of Dr. T. Namekawa, Professor of Meteorology, Kyoto University. During this study, the writer found a peculiar oscillation on the microbarograms in the early morning on 27 th Mar. 1954 (see Fig. 4a). Remembering a curious microbarographic oscillation caused by the great Siberian meteor fall on 30 th June 1908[2], the author had a question whether the oscillation on 27 th Mar. 1954 might have been produced by the explosion of Hydrogen-Bomb at Bikini.

Wave-like fluctuations from meteorological origins frequently appear on the microbarograms. Such waves have commonly the propagation velocities of internal gravitational waves at the surface of discontinuity. The velocity of propagation of this kind is comparatively small; i.e. it is very rare to exceed 40 m/sec and even a wave with an exceptionally high velocity discovered by T. Namekawa[3] has that of about 60 m/sec.

On the other hand, the observed propagation velocities of waves by the Krakatoa eruption[4] and by the great Siberian meteor fall[2] are nearly sound velocity ; i.e. 318. 8 m/sec for the former and 318 m/sec for the latter. As the theoretical value of propagation velocity of the external gravitational wave is nearly sound velocity, the microbarographic oscillations with about sound velocity are treated as the results of such waves produced by some large scale disturbances; i.e. volcanic eruption and so on.

Accordingly, the propagation velocity of microbarographic wave gives us a criterion whether the wave is resulted from the ordinary meteorological origin or explosive one. For this purpose, the author has collected the microbarograms and barograms with high sensibility as many as possible in Japan, and he confirmed that the wave in question propagated with about sound velocity. Similar microbarographic waves are observed on 1st Nov. 1952, 1st Mar. 1954, 26th Apr. 1954 and

5th May 1954. In this primary report the observational materials are mainly shown.

II. LIST OF MICROBAROGRAPHIC AND BAROGRAPHIC OBSERVATIONS IN JAPAN.

Specifications and locations of the microbarographic and barographic observations which supply the records available for our investigation are listed in the following. Fig. 1a and 1b are the maps showing the positions of the stations.

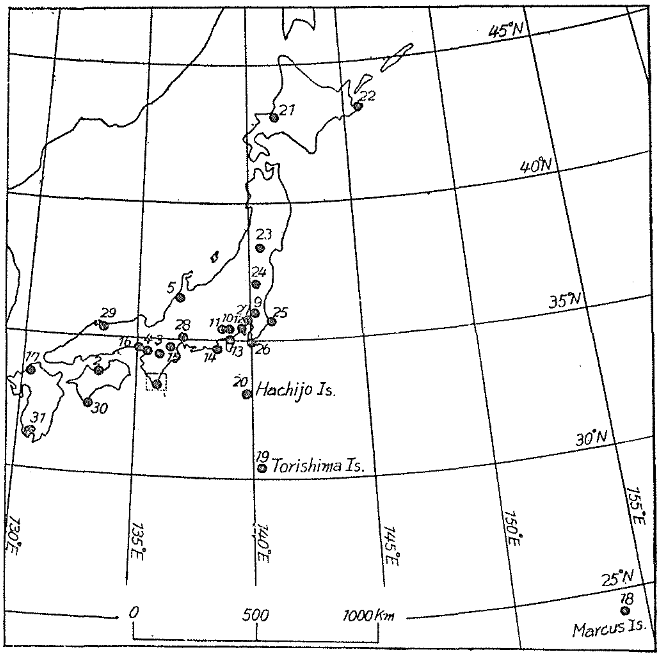

Fig. 1a Map showing the positions of stations of microbarographic and barographic observation available for our investigation. Station number is given at the side of the dot.

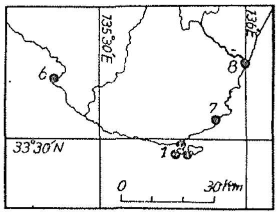

Fig. 1b Map near Shionomisaki. This shows our network of microbarographic observations.

(a) T. Shida's Leaking Microbarograph[1]

Instrument : A modified form of U-tube manometer with magnification power : ca. 40 (1 mm Hg ≒ 40 mm on record)
leakage coefficient : ca. 9.0×10^{-4}

Authority : Meteorological Institute of Kyoto University.

Station number	Location	Lat. (N)	Long. (E)
1	3 points near Shionomisaki Meteorological Station	33° 27′	135° 46′

(b) Shaw-Dines' Microbarograph

Instrument : constructed by Tatsutoshi Takahashi at Niihama High School, former assistant of Meteorological Institute of Kyoto University.

magnification power : ca. 15

Station number	Location	Lat. (N)	Long. (E)
2	Niihama	33° 56′	133° 18′

Authority : T. Takahashi

S. Suzuki's Barovariograph[5]

Instrument : Shaw-Dines' microbarograph with sufficient leakage

Station number	Location	Lat. (N)	Long. (E)	Magnification power*	Authority
3	Nara	34° 38′	135° 50′	ca. 660	S. Suzuki
4	Osaka	34 39	135 32	ca. 660	S. Suzuki
5	Kanazawa	36 32	136 39	ca. 150	K. Ito, Director of Kanazawa Meteorological Station.

* "magnification power : 660" in this column means "1 mmHg/sec=660 mm on record"

(c) Statoscope with Leakage

Station number	Location	Lat. (N)	Long. (E)	Magnification power	Authority
6	Shirahama	33° 40′	135° 21′	ca. 10	Meteorological Institute of Kyoto University
7	Uragami	33 33	135 54	ca. 5	
8	Shingu	33 43	136 00	ca. 5	
9	Kashiwa	35 51	139 59	ca. 20	Central Meteorological Observatory of Japan
10	Gotenba	35 19	138 56	ca. 20	
11	Tarobo	35 19	138 49	ca. 20	

(d) Sprung's Barograph

magnification power : ca. 10

Station number	Location	Lat. (N)	Long. (E)
12	Yokohama	35° 26′	139° 39′
13	Mishima	35 07	138 57
14	Omaezaki	34 36	138 13
15	Kameyama	34 51	136 28
16	Kobe	34 41	135 11
17	Fukuoka	33 35	130 23

Authority : Central Meteorological Observatory of Japan.

(e) Barograph (Richard's Type)
magnification power : ca. 2

Station number	Location	Lat. (N)	Long. (E)
18	Marcus Is.	24° 47′	154° 20′
19	Torishima Is.	30 29	140 18
20	Hachijo Is.	33 06	139 50
21	Sapporo	43 04	141 20
22	Nemuro	43 20	145 35
23	Yamagata	38 15	140 21
24	Shirakawa	37 07	140 13
25	Choshi	35 44	140 52
26	Tomisaki	34 55	139 50
27	Tokyo	35 41	139 46
28	Nagoya	35 10	136 58
29	Yonago	35 26	133 21
30	Ashizurimisaki	31 34	130 33
31	Kagoshima	32 45	130 00

Authority : Central Meteorological Observatory of Japan.

III, THE PROPAGATION VELOCITY OF THE AIR WAVES RESULTED FROM THE EXPLOSIONS OF HYDROGEN-BOMBS.

The propagation velocity of the waves in question can be found by a method of the phase identification. At first, we must select the most distinct phase to be identified from among the whole disturbance shown on the microbarograms. The writer selects the first trough of the disturbance shown on Shida's microbarograms (see Figs. 2a, 3a, 4a, 5a, and 6a). On the records of the other stations, this phase, which is

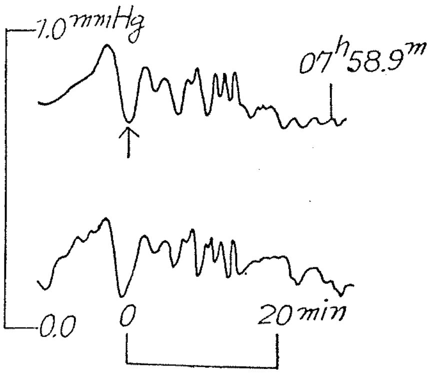

Fig. 2a Shida's microbarograms at Shionomisaki on 1st Nov. 1952 (original size)

indicated by arrows on the microbarograms and barograms, is also enough distinct to

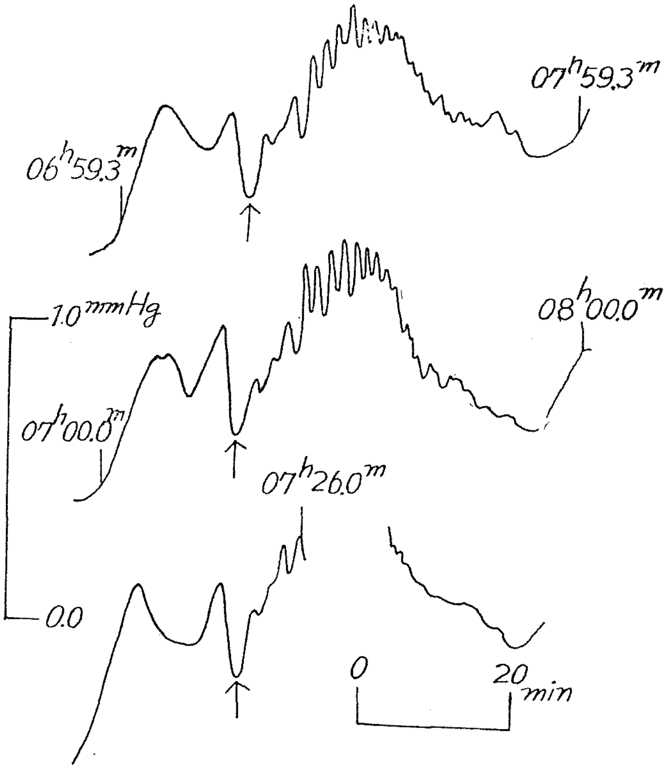

Fig. 3a Shida's microbarograms at Shionomisaki on 1st Mar. 1954 (original size)

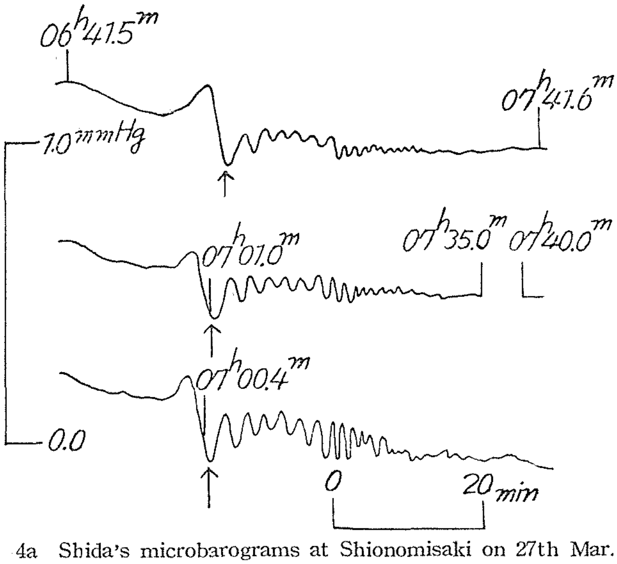

Fig. 4a Shida's microbarograms at Shionomisaki on 27th Mar. 1954 (original size)

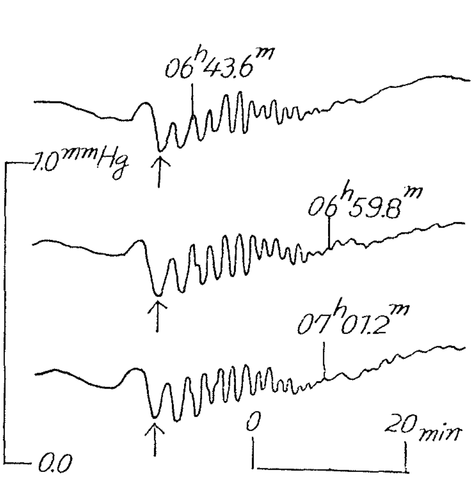

Fig. 5a Shida's microbarograms at Shionomisaki on 26th Apr. 1954 (original size)

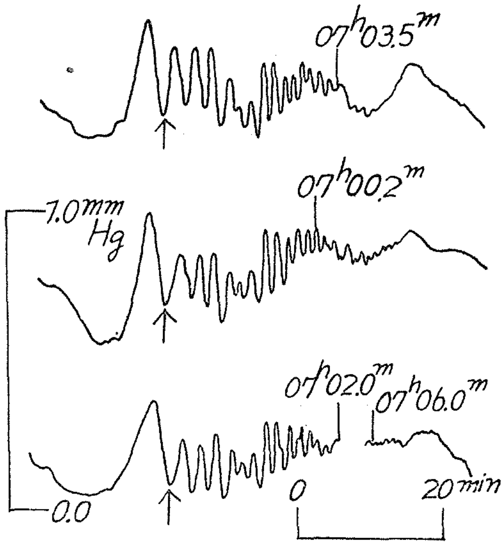

Fig. 6a Shida's microbarograms at Shionomisaki on 5th May 1954 (original size)

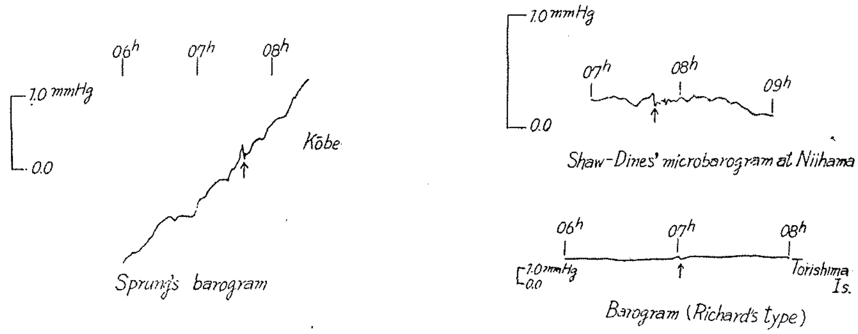

Fig. 2b Microbarogram and barograms on 1st Nov. 1952 (original size)

be identified (see Figs. 2b, 3b, 4b, 5b, and 6b).

The occurrence times * of this phase (first trough) on the records are listed in Table 1.

The plausible isochronous lines, which show the progressive nature of the identified phase (first trough), are drawn on a map for each case after smoothing the accidental and local irregularities which appear on the occurrence times listed in Table 1. Such a chart for 1st Mar. 1954, as an example, is shown in Fig. 7. This chart shows that the speed of the wave is nearly equal to sound velocity

* Japan Standard Time at 135°E (J. S. T.) is used in this paper, unless otherwise mentioned.

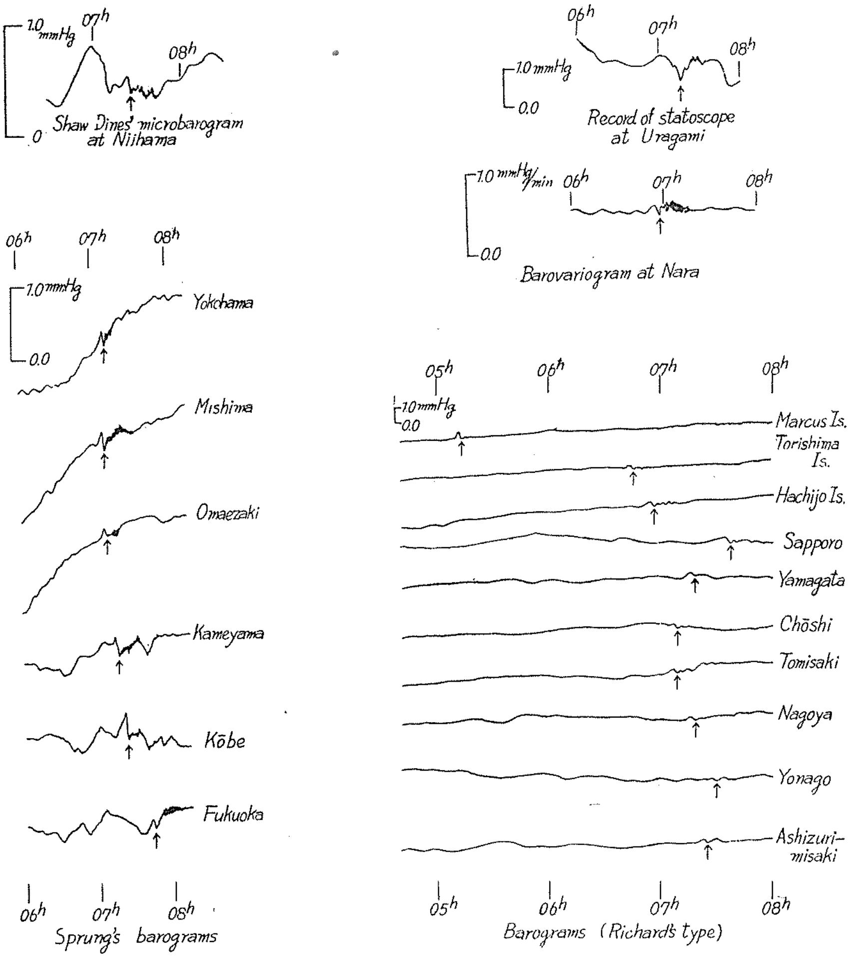

Fig. 3b Microbarograms and barograms on 1st Mar. 1954 (orignal size)

and the direction of the wave almost coincides with what comes from Bikini. Similar facts also appear in the charts of all the other cases. Accordingly we may conclude that the microbarographic oscillations are produced by the explosions of Hydrogen-Bombs at Bikini.

The propagation velocity may be calculated from the isochronous chart, but the method contains some arbitrariness. To find the numerical value of the propagation velocity as accurately as possible, the writer takes a method of triangular phase identification, selecting the three most reliable stations from among the network. For this purpose, Shionomisaki is selected as one station, which may give the most accurate data by Shida's microbarograms, and as the remaining two stations the nearest ones to Bikini; i.e. Torishima Is. and Marcus Is. are selected.

The propagation velocities obtained in this way are listed in Table 2, and by assuming that each wave travels with this velocity, the author calculates the probable times of the explosions at Bikini, which are also given in that table.

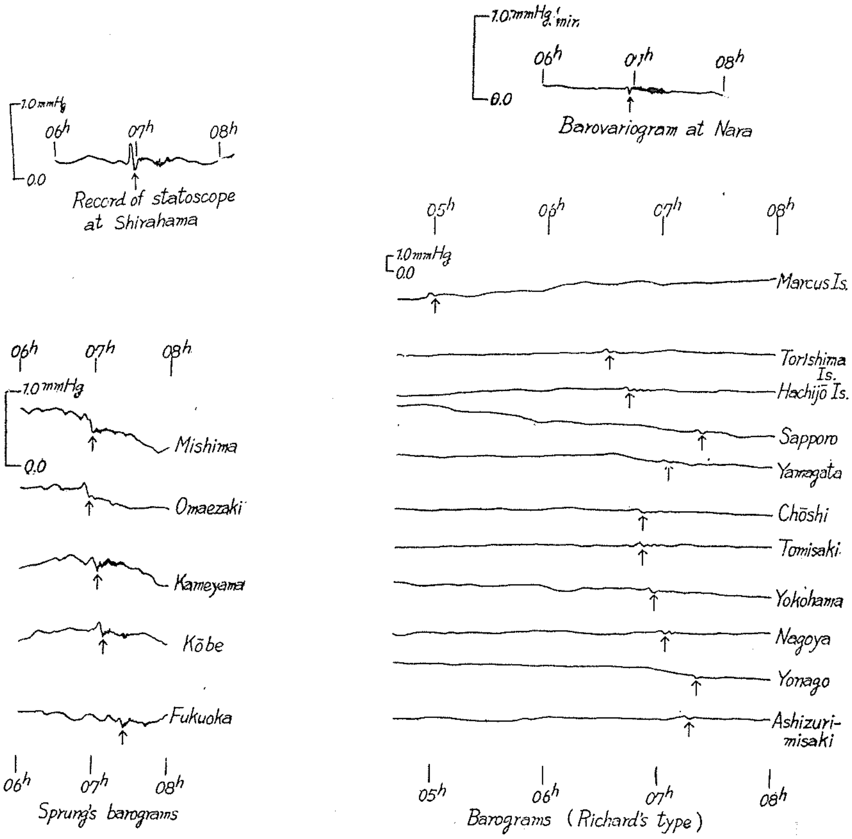

Fig. 4b. Microbarograms and barograms on 27th Mar. 1954 (original size)

IV. REMARKS

(1) It had been shown by the barograms that the air wave by the Krakatoa eruption went round the globe several times, taking about 35 hours over one revolution. The similar evidences did not appear in our cases ; i.e. any appreciable trace on the microbarograms at Shionomisaki did not appear at the expected time of about 30 hours later from the original passage (the primary wave passing through the antipode) or about 40 hours later (the secondary wave after one revolution over the globe).

(2) The seismic waves were also observed in the case of the great Siberian meteor fall. The similar evidence could not be found by the examination of Wiechert's seismograms (magnification power ca. 200) at Kamigamo Geophysical Observatory of Kyoto University.

(3) The examination for finding any corresponding disturbances on the

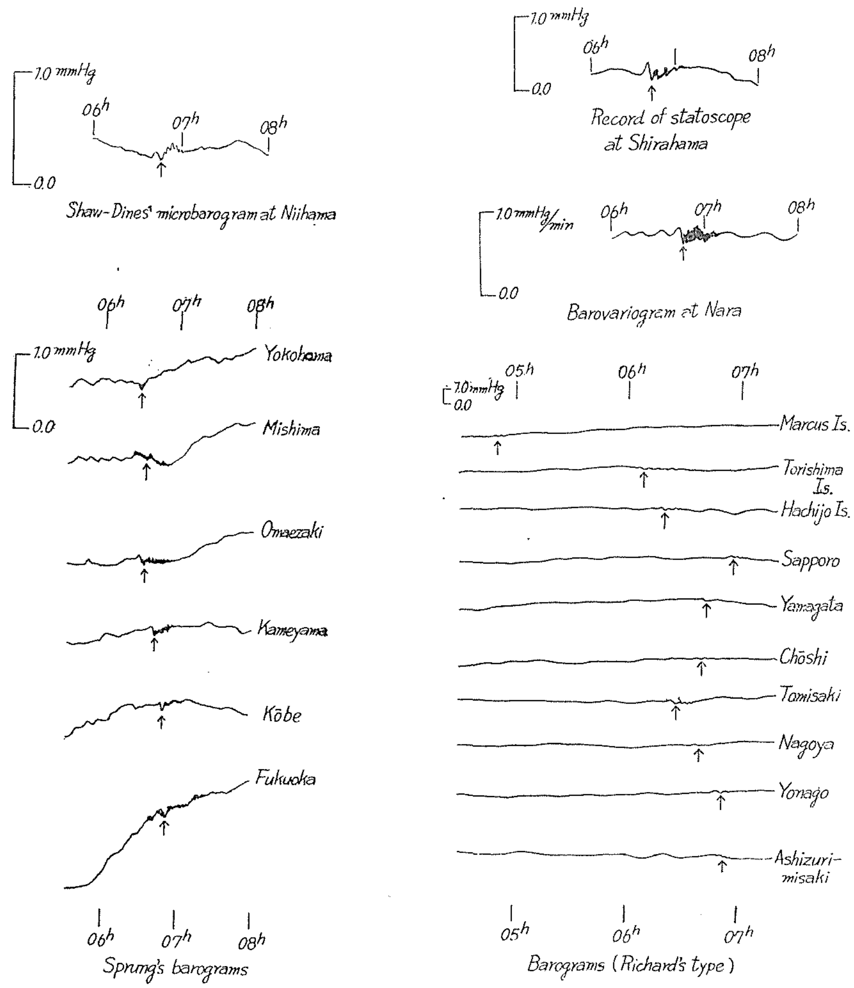

Fig. 5b Microbarograms and barograms on 26th Apr. 1954 (original size)

mareograms at Kushimoto Harbour near Shionomisaki seems to succeed, although not conclusive. On the reproduced mareograms shown in Fig. 8, we can see that the initiation of the remarkable secondary undulations with period about 12 min. or 17 min. [theoretical period: ca. 13 min. (for bay: length≒1.2 km, depth≒4.2 m) and ca. 18 min. (for bay: length≒2.8 km, depth≒10.5m)] always accompany in all the cases in question. Now we may presume that the phase of the initiation of the corresponding changes are points indicated by arrows on the reproduced records. These phase times are listed in the second column of Table 3.

The velocity of propagation of the sea disturbance in question can be easily calculated by knowing the phase time of initiation, the time of the explosion and the distance from Kushimoto to Bikini (3910 km). The obtained numerical values are listed in the seventh column of Table 3. Furthermore, if we assume this disturbance propagates with the velocity of long wave; i.e. $\sqrt{gH}$ (g: the gravita-

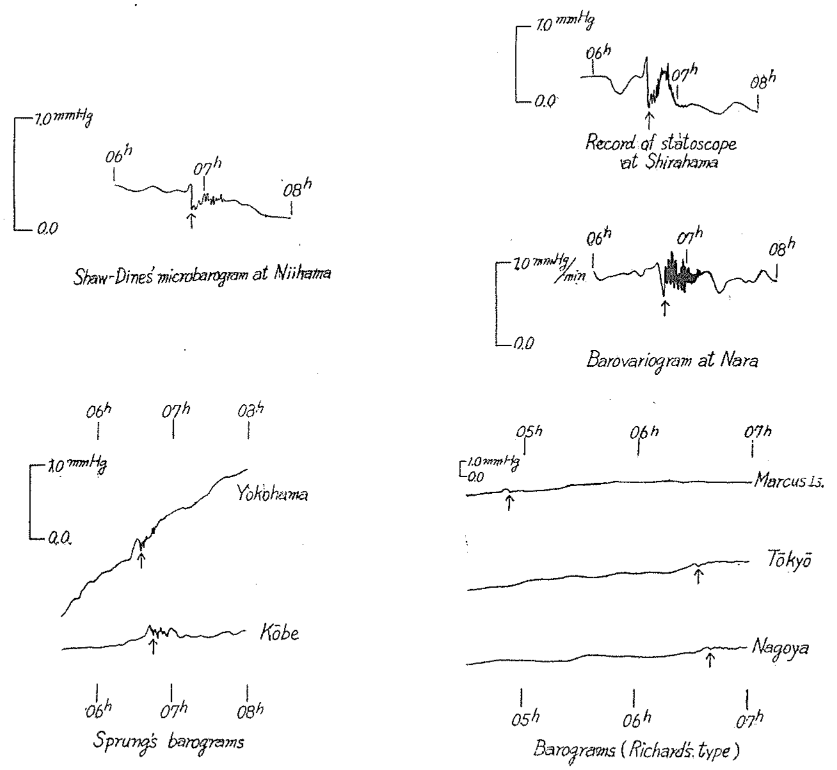

Fig. 6b Microbarograms and barograms on 5th May 1954 (original size)

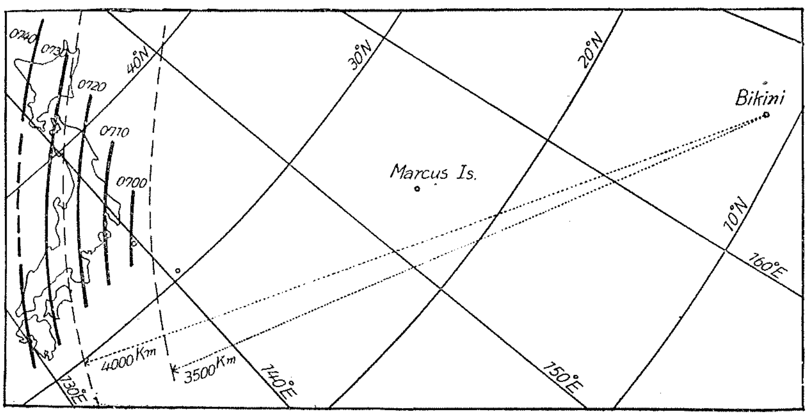

Fig. 7 Isochronous chart on 1st Mar. 1954

tional acceleration), the mean depth H must be 3.6—4.1 km, which shows a good agreement with the actual mean depth of the Pacific Ocean from Kushimoto to

Table 1

Station number	Station	Distance from Bikini (km)	1st Nov. 1952	1st Mar. 1954	27th Mar. 1954	26th Apr. 1954	5th May 1954
1	Shionomisaki	3910	07h30.9m	07h17.1m 07 17.2 07 17.3	07h01.5m 07 01.2 07 01.4	06h39.6m 06 39.6 06 40.0	06h40.9m 06 41.3 06 40.6
2	Niihama	4140	07 43	07 30	....	06 48	06 54
3	Nara	3960	....	07 18	06 59	06 43	06 47
4	Osaka	4000	....	....	....	06 47	06 48
5	Kanazawa	4030	07 42	07 29	07 14	....	06 53
6	Shirahama	3960	....	07 18	07 00	06 42	06 42
7	Uragami	3910	....	07 16	06 59	06 40	06 41
8	Shingu	3910	....	07 19	06 57	06 42	06 42
9	Kashiwa	3740	....	....	....	06 32	
10	Gotenba	3780	....	....	....	06 34	06 35
11	Tarobo	3790	....	....	....	06 32	
12	Yokohama	3740		07 10	06 56	06 33	06 33
13	Mishima	3770		07 10	06 59	06 37	
14	Omaezaki	3790		07 11	06 54	06 34	
15	Kameyama	3940		07 18	07 02	06 40	
16	Kobe	4030	07 37	07 26	07 09	06 48	06 50
17	Fukuoka	4360		07 42	07 25	06 51	
18	Marcus Is.	1900		05 16	05 03	04 52	04 51
19	Torishima Is.	3370	07 01	06 47	06 31	06 08	
20	Hachijo Is.	3590		06 58	06 45	06 19	
21	Sapporo	4210		07 34	07 23	06 58	
22	Nemuro	4020	07 47	07 26	07 16	06 52	06 51
23	Yamagata	3890		07 18	07 03	06 41	
24	Shirakawa	3820		07 17	06 59	06 39	
25	Choshi	3670		07 07	06 48	06 31	
26	Tomisaki	3690		07 06	06 51	06 27	
27	Tokyo	3750					06 34
28	Nagoya	3920		07 17	07 04	06 39	06 41
29	Yonago	4210	07 50	07 27	07 21	06 53	07 00
30	Ashizurimisaki	4100		07 24	07 15	06 54	
31	Kagoshima	4250	08 05	07 40	07 22	06 57	07 04

Table 2

Date	Velocity of propagation computed from the records at Shionomisaki, Marcus Is.and Torishima Is. (m/sec)	Probable time of explosion	
		(J.S.T.)	(G.M.T.) on the previous day.
1st Nov. 1952	298	03h52m	18h52m
1st Mar. 1954	284	03 28	18 28
27th Mar. 1954	287	03 14	18 14
26th Apr. 1954	304	03 06	18 06
5th May 1954	310	03 10	18 10

Bikini.

(4) The detection of the explosive wave by Shida's microbarographs at

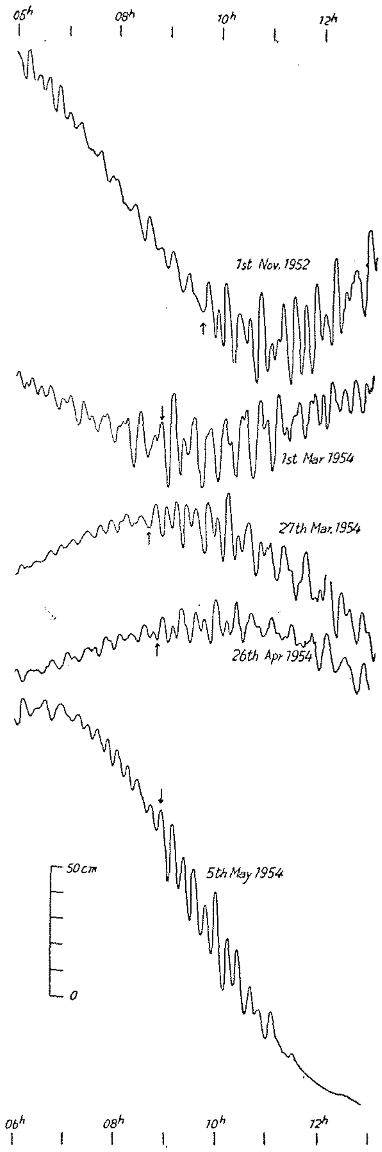

Fig.8 Mareograms at Kushimoto (1/3 of original size)

Shionomisaki fails in the reported U. S. S. R. explosions of Hydrogen-Bombs in Aug. 1953, and also in the reported U. S. A. explosions of atomic bombs of several cases since Jan. 1952.

(5) Although our computed propagation velocities are nearly equal to sound velocity, the numerical values of 284m/sec-310m/sec do not exactly coincide with

Table 3

Date	Initiation time of the disturbance on the mareogram (J.S.T.)	Duration time of the disturbance on the mareogram (min.)	Maximum amplitude (cm)	Mean period (min.)	Probable time of explosion (J.S.T.)	Velocity of propagation (m/sec)	H (km)
1st Nov. 1952	09h37m	135	18	11.8	03h52m	189	3.63
1st Mar. 1954	08 52	129	19	17.2	03 28	201	4.12
27th Mar. 1954	08 40	113	14	12.0	03 14	201	4.12
26th Apr. 1954	08 50	95	10	12.4	03 06	190	3.69
5th May 1954	08 53	122	16	12.3	03 10	190	3.69

318.8m/sec in the Krakatoa eruption or 318m/sec in the great Siberian meteor fall. We must remember that some inaccuracy may arise from the smallness of the triangle obliged to apply in our method. However, we can find that the velocities of propagation listed in Table 2 have a tendency of increasing with the progress of season, cold to warm. Referring that the Krakatoa eruption occurred in August and the great Siberian meteor fall in June, the existence of seasonal variation of the propagation velocity may be presumed. And this fact may give an explanation why our obtained velocities are smaller than the others.

Theoretically speaking, increase of the temperature of the whole atmospheric column increases the propagation velocity of long gravitational wave of the atmosphere. Furthermore, the velocity of propagation may be expected to be influenced by summer SE-ly wind in our locality. Detailed examination in this respect cannot be afforded at present owing to the lack of available materials. The slight lobbing of the north-east part of the isochronous lines appearing in Fig. 7 seems to give some suggestion to this problem.

(6) It is noticed by F. J. W. Whipple[2] that the air wave by the great Siberian meteor fall have a predominant period about 2 min, which is followed by more sudden oscillation with period less than 1 min. The similar fact can be found on Shida's microbarograms at Shionomisaki in our all cases. (e. g. see Fig. 4a)

The dynamical explanation of this serious characteristic is now attacked by the author. He shows that among the internal gravitational waves at the surface of discontinuity of 40 km level above the ground, the waves of period 2 min. and 1 min. propagating with about sound velocity can be founddynam ically satisfying the condition of the non-cellular solution in the upper layer and the cellular or non-cellular solution in the lower layer, a necessary condition for trapping of the energy in the lower layer. The complete discussion is now prepared.

(7) The comparative examination of the records of barometric waves at various stations enable us to see that the wave in question does not propagate with invariable shape, but with changing one as time passes. The very remarkable

first high followed by the shallow first trough appears on the records of Marcus Is., nearest station to Bikini (ca. 1900 km) in our network in all the cases except 26th Apr. 1954 (see Fig. 5b). This characteristic of the shape of barometric waves appears at Torishima Is. as the slightly diminishing first high with developing first trough, and at Hachijo Is. the first high is much damped and followed by well developing first trough with the distinct oscillatory disturbances in succession. This fact suggests that the wave in question has a dispersive character, which must be taken into account in the theory of the wave of this kind.

(8) A different type of the disturbances which give the oscillatory fluctuation only, appeared on 26 th Apr. 1954 at Marcus Is. and Torishima Is., while no similar abnormality is found at the various stations in Japan proper on that day. The cause of this fact is not clear, but the some dependency on the mode of the explosion of Hydrogen-Bomb is suggestive.

(9) Whipple's method[2] of finding the magnitude of energy of the explosion supplied to the atmosphere by the microbarographic trace is very attractive.

Table 4

Date	1st Nov. 1952	1st Mar. 1954	27th Mar. 1954	26th Apr. 1954	5th May 1954	Great Siberian meteor fall
Computed energy of the atmospheric oscillation in ergs.	5.0×10^{20}	13.8×10^{20}	5.6×10^{20}	3.5×10^{20}	14.2×10^{20}	3.2×10^{20}

Remaining the full discussion for the justification of the various assumptions involved in his method, the writer employed this method and obtained the results given in Table 4.

ACKNOWLEDGEMENTS

I would like to express my gratitude to Professor T.Namekawa for his interest in this subject and for leading me. I am indebted to Mr. T. Takahashi, Dr. S. Suzuki and the director of Central Meteorological Observatory of Japan for the permission of reproduction of the microbarograms and barograms shown in Figs. 2b, 3b, 4b, 5b and 6b, and to the director of Shionomisaki Meteorological Station for the permission of reproduction of the mareograms at Kushimoto given in Fig. 8. I am grateful to Professor E. Nishimura, who permitted to examine the seismograms at Kamigamo Geophysical Observatory of Kyoto University. This work was partly supported by the research grant from the Ministry of Education.

REFERENCES

(1) T. Namekawa ; *Mem. Coll. Scie., Kyoto Imp. Univ., A*, **19**, 237 (1936)
(2) F. J. W. Whipple ; *Quart. J. Roy. Met. Soc.*, **56**, 287 (1930)
(3) T. Namekawa ; *Mem. Coll. Scie. Kyoto Imp. Univ., A.*, **18**, 173 (1935)
(4) Krakatoa Committee ; The Eruption of Krakatoa and its Subsequent Phenomena (1888)
(5) S. Suzuki ; Proc. *Phys.- Math. Soc. Japan, Ser. 3*, **10**, 181 (1928)